STIF

07

III

77-10220
CR-154803

INVESTIGATION OF THE EFFECTS OF CONSTRUCTION AND STAGE FILLING OF RESERVOIRS ON THE ENVIRONMENT AND ECOLOGY: PREPROJECT BASELINE

R. E. Riggins
J. R. Anderson

Department of the Army
Construction Engineering Research Laboratory
P.O. Box 4005
Champaign, IL 61820

(E77-10220) INVESTIGATION OF THE EFFECTS OF CONSTRUCTION AND STAGE FILLING OF RESERVOIRS ON THE ENVIRONMENT AND ECOLOGY: PREPROJECT BASELINE Final Report (Army Construction Engineering Research Lab.) 44 p HC A03/MF A01 G3/43 N77-31574 Unclas 00220

May 1977
Final Report

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

Original photography may be purchased from:
EROS Data Center
[redacted]
Sioux Falls, SD 57198

Prepared for
GODDARD SPACE FLIGHT CENTER
Greenbelt, MD 20771

23500

Approved for public release; distribution unlimited.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle INVESTIGATION OF THE EFFECTS OF CONSTRUCTION AND STAGE FILLING OF RESERVOIRS ON THE ENVIRONMENT AND ECOLOGY: PREPROJECT BASELINE

5. Report Date May 1977

6. Performing Organization Code

7. Author(s) R. E. Riggins, J. R. Anderson

8. Performing Organization Report No. CERL-TR-N-24

9. Performing Organization Name and Address
CONSTRUCTION ENGINEERING RESEARCH LABORATORY
P.O. Box 4005
Champaign, IL 61820

10. Work Unit No.

11. Contract or Grant No. S-53875

12. Sponsoring Agency Name and Address
Goddard Space Flight Center
Greenbelt, MD 20771
Harold Oseroff, Technical Monitor

13. Type of Report and Period Covered Final

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Landsat imagery was used to produce enhanced color composite enlargements of an area in northeastern Missouri undergoing reservoir development. Preproject environmental conditions were recorded in multi-seasonal images; forest cover was delineated from these images and compared to ground truth. Line printed output from Landsat Computer-Compatible Tape was also used in the comparison. Landsat imagery was used to detect major environmental changes resulting from dam construction, clearing, and recreational development. High-altitude aerial imagery was used to develop a generalized land use map and a predicted forest type distribution map.

17. Key Words (Selected by Author(s))
reservoir construction
reservoir stage filling
ecology
high-altitude aerial and satellite imagery

18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
UNCLASSIFIED	UNCLASSIFIED	38	

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

PREFACE

The purpose of this work was to develop a preproject environmental baseline so that environmental changes that occur during construction and operation of an inland reservoir can be identified. It is the second of an anticipated series of investigations to measure changes in the ecology of a river basin using high-altitude aerial and satellite imagery.

Multi-seasonal Landsat images were used to record preproject environmental conditions of an area in northeastern Missouri undergoing reservoir development. Later Landsat images were used to identify changes. High-altitude aircraft images and line print output from Landsat Computer-Compatible Tape were used for comparison.

Forest cover could be accurately identified using multi-seasonal imagery delineated with a dual image mapping technique. Results were comparable to ground truth at a scale of 1:250,000. Major changes from dam construction, clearing, and recreational development could be identified.

High-altitude aerial imagery was also used to develop preproject land use and vegetation patterns. A generalized land use map was produced on a regional scale that identified forest, pasture, and row crop land. A predicted forest type map was developed using a more detailed approach. This map yielded an accurate baseline of vegetation conditions. Continued monitoring of the project area is needed to identify and measure post-project environmental changes.

TABLE OF CONTENTS

[redacted]

LIST OF ILLUSTRATIONS

LIST OF TABLES

1 INTRODUCTION

OBJECTIVE

The overall objective of the anticipated series of investigations is to test two hypotheses: (1) that environmental changes which take place in a river basin during construction and long-term operation of a flood-control reservoir can be measured by high-level aerial and satellite photography and other data, and (2) that post-project changes in areas having similar preproject environments can be predicted with reasonable accuracy.

Previous work developed a monitoring system which includes a simple information-extraction technique based on optical processing. The purpose of the work reported herein was to develop a preproject environmental baseline which will permit identification of post-project changes. The process for developing the baseline was compared to machine processing techniques, and the results were evaluated by comparison with ground truth.

PROJECT AREA

The Clarence Cannon Dam and Reservoir is located on the Salt River in northeastern Missouri (Figures 1 and 2).[1] The project area covers 214.4 km^2 (52,985 acres)* over portions of five counties. Approximately 80 km^2 (20,000 acres) of land will be cleared to make way for a 75 km^2 (18,600 surface acre) lake. Work was concentrated at the dam site between 1966, when construction began, and 1976, when clearing and recreational development were initiated. The project is scheduled for completion in 1978.

Within the project area, two types of land use patterns dominate. The uplands and valley sides are agricultural, while the steep slopes and valley bottoms are forested. The Salt River is characterized by a variety of habitat types, ranging from long, quiescent pools to fast-moving riffles. The dam will transform this water system into a standing body of water and will permanently inundate acres of wooded hills and bottomland; a comparable amount of acreage will occasionally be flooded. Downstream reaches will experience reduced flooding.

Although the environmental effects in areas which are occasionally flooded are difficult to predict, dramatic shifts in abundance are expected for most species. The degree of change expected is indicated by

[1]Final Environmental Impact Statement, Clarence Cannon Dam and Reservoir. U.S. Army Corps of Engineers, St. Louis District, October 1974

*Measurements given in dual units were originally measured in U.S. customary units. Where only SI units are given, the measurements were originally recorded in those units.

CORPS OF ENGINEERS U. S. ARMY

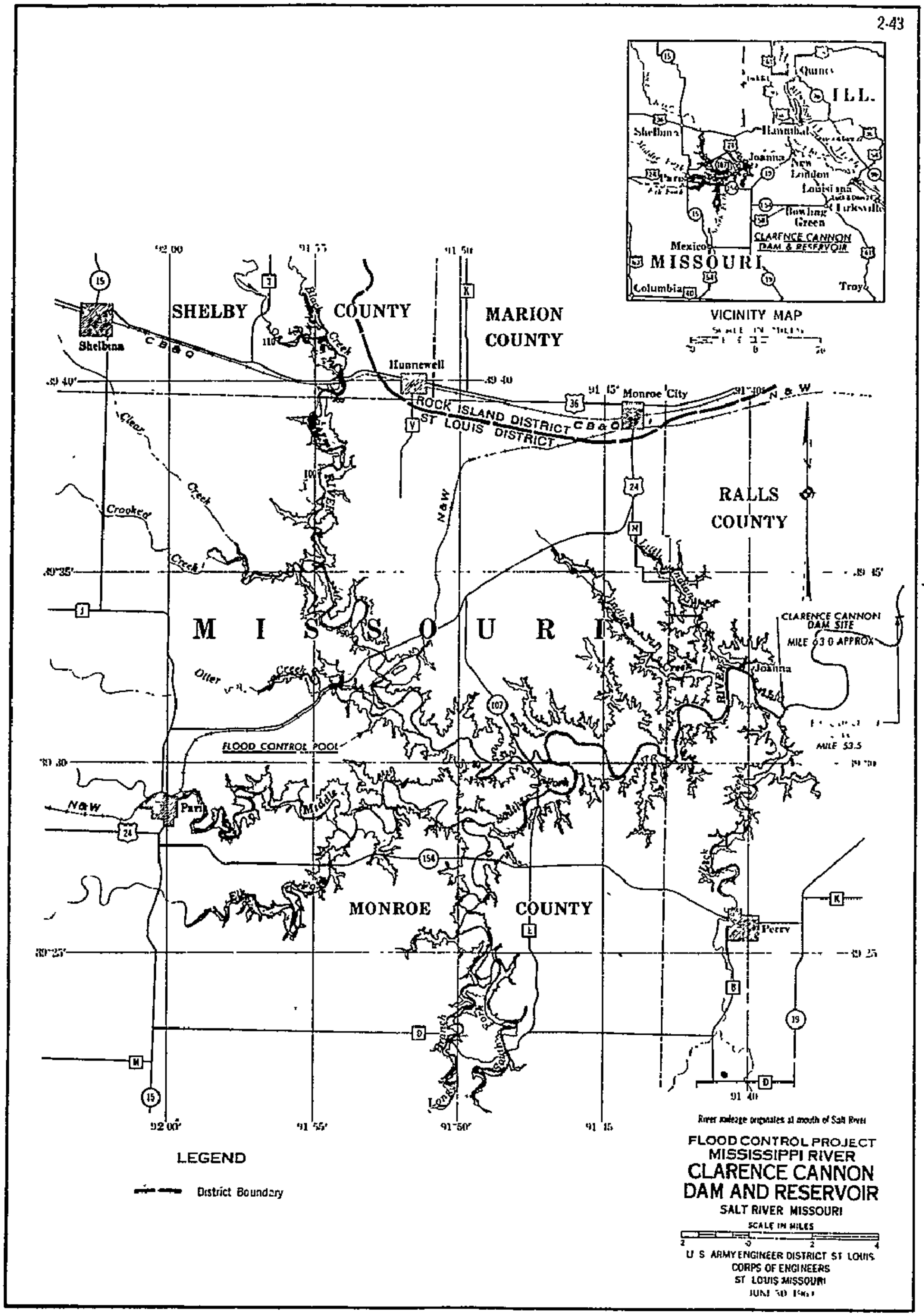


Figure 1. Clarence Cannon Dam and Reservoir

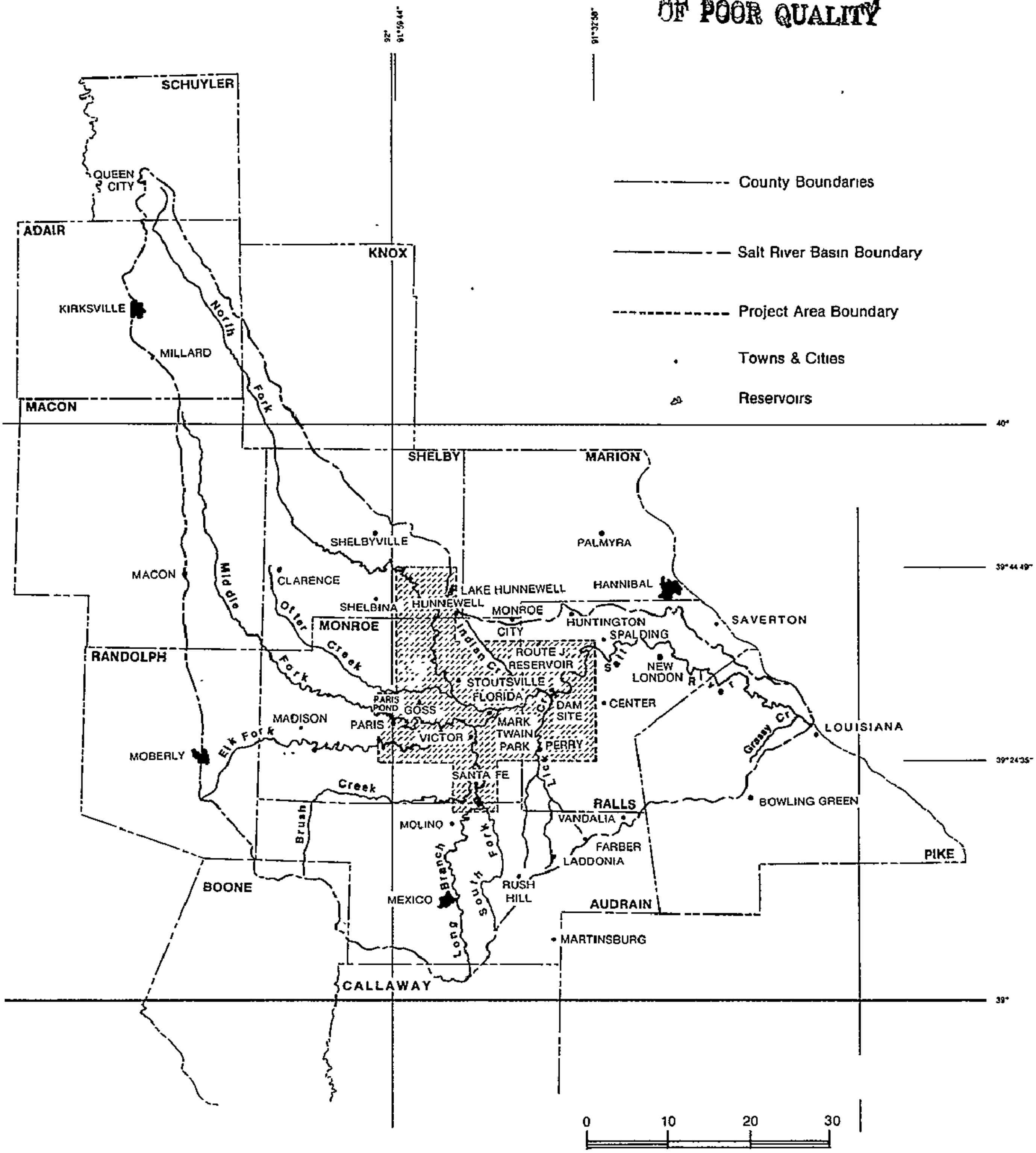


Figure 2. Basin Map

a statement from the project's Environmental Impact Assessment: "such alterations are nothing short of biological catastrophies, and it will take a period of time for these systems to readjust to the new conditions."[2] It could take 10 or more years for biological transformation to stabilize.

Ground truth for this study was provided by the documents referenced above. Forest cover was of particular interest for several reasons: it is observable on small-scale imagery; about 39 percent of the project area is forested; and, as habitat, forest cover is an indication of other ecological conditions. The forest cover map shown in Figure 3 was compiled from data presented in the project's Environmental Impact Assessment.

Appendix A describes the imagery available for the project area.

[2]Environmental Impact Assessment, Clarence Cannon Dam and Reservoir. Final Report to the U.S. Army Corps of Engineers, St. Louis District. Missouri Botanical Garden, October 1974

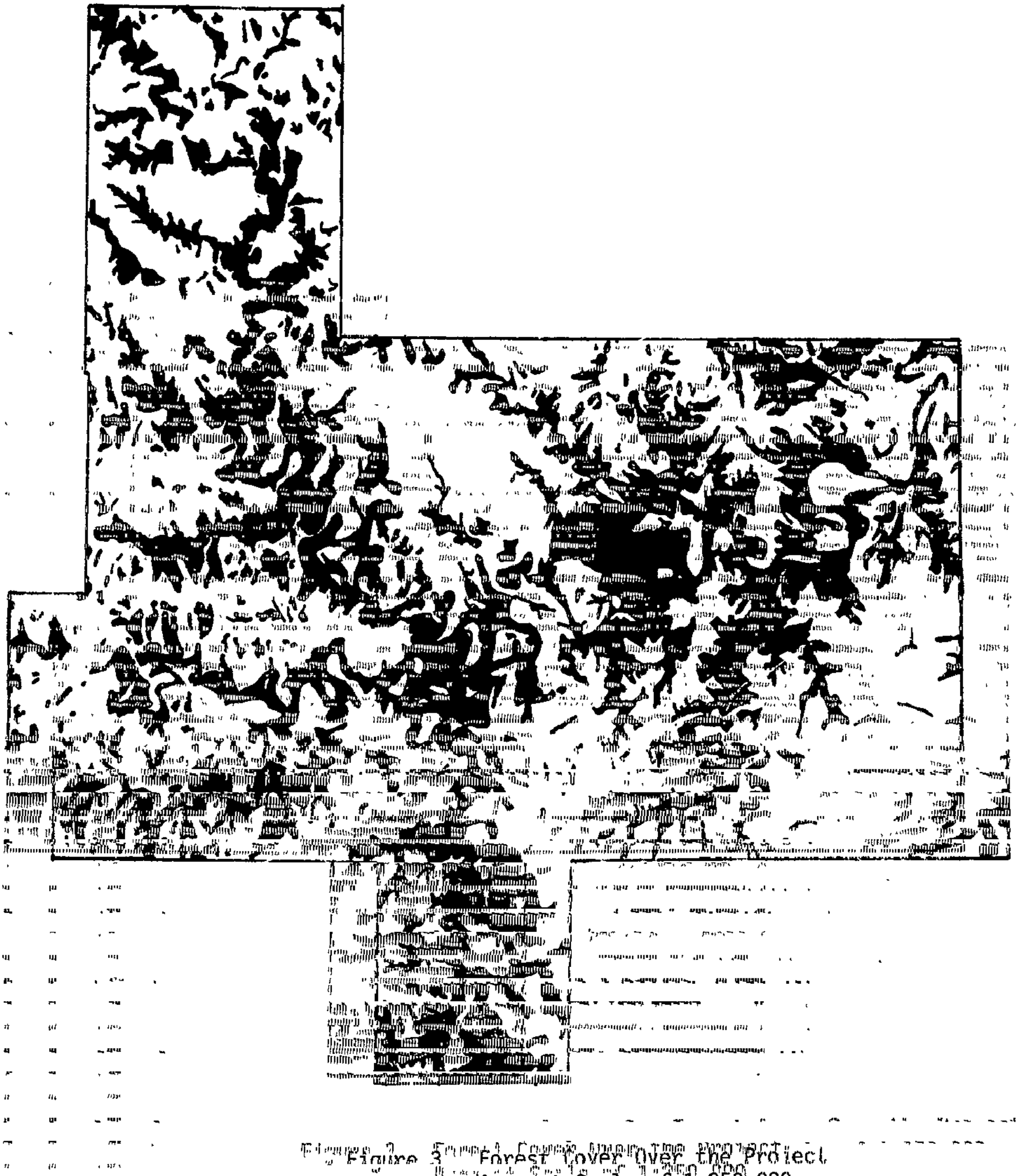


Figure 3 Forest Cover Over the Project Area at Scale of 1:250,000

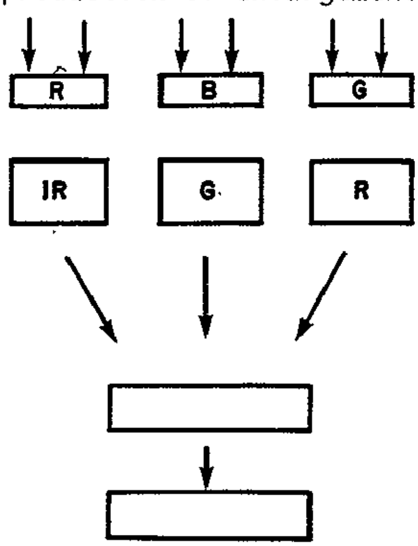
2 OPTICAL PROCESSING OF LANDSAT IMAGERY

APPROACH

Optical processing is the use of photographic techniques to enhance a photographic image and facilitate information extraction. The photograph is a physical record of the radiation reflected from the ground. Optical processing can be carried out with the photographic image from a point perspective sensing system (camera) or from a line scanning or vidicon system. The information (spectrally) is the indication of which band (wavelength) and how much of the radiation (intensity as indicated by gray level or density) is being reflected.

The several techniques which can be used to produce enhanced imagery are discussed in detail in a previous report.[3] The following paragraphs describe the steps used in this study to prepare enhancements for extraction of environmental baseline information.

Because the project area is contained in a small area of the Landsat image, enlargement and contrast enhancement could be accomplished at the same time. A Nikon F 35 mm camera with a PB-5 bellows focusing attachment permitted enlargements from .8X to 4X. Black and white positive records were exposed individually in register through color filters to produce high-contrast color slides on Ekco photomicrography film 2483. Figure 4 depicts the process, and Appendix B provides additional information on the production of enlargements.



-Printing filter

-Positive black and white record

-Printed one at a time in register

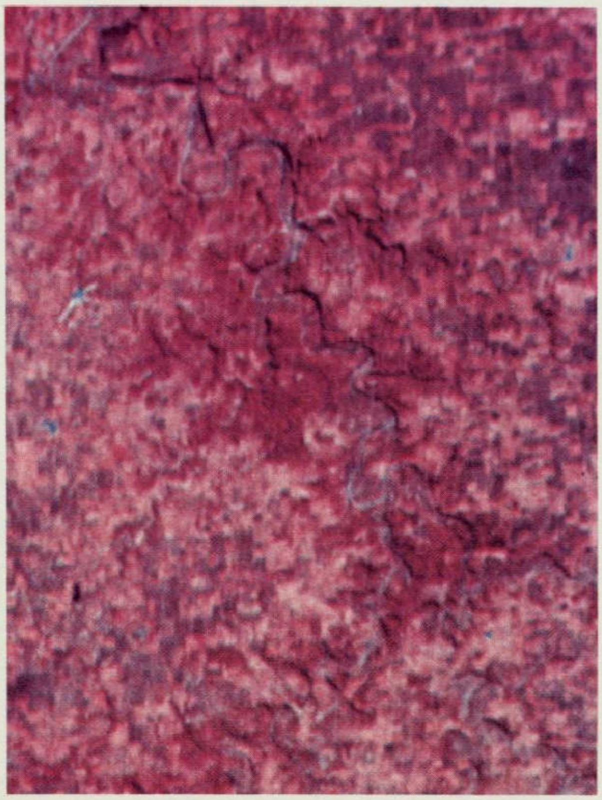
-Color negative film or photomicrography film

-Color print paper (+ color print)

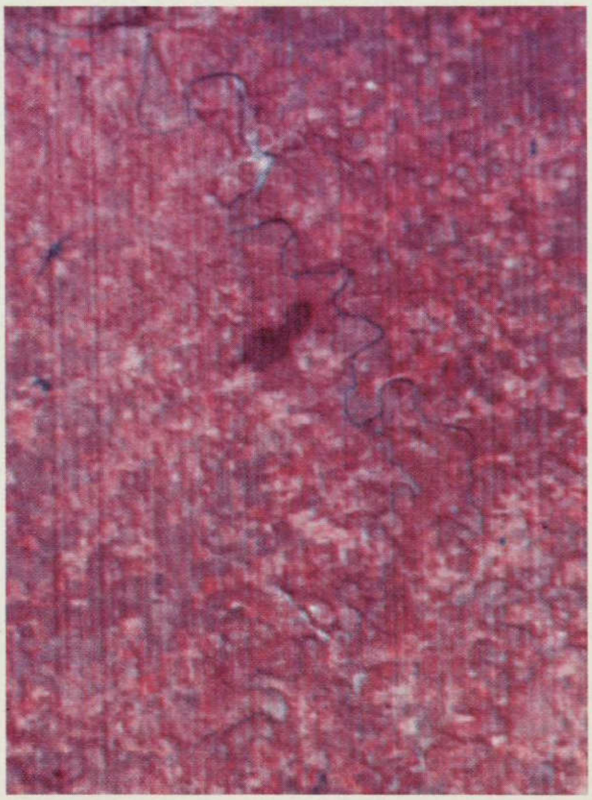
Figure 4. Additive Printing of Positive Black and White Records

[3]R. E. Riggins and R. K. Jain. Investigation of the Effects of Construction and Stage Filling of Reservoirs on the Environment and Ecology. Final Report. Goddard Space Flight Center, 1975

Enhancements were produced for each month of the year to determine the best representations of forest cover. In general, although imagery from any month can provide some information about forest cover, no single time period gives a complete and accurate representation for interpretation. Winter scenes such as Figures 5a and 5b show densely forested areas, but areas of light forest cover are not easily detected. Barren or plowed fields can be misinterpreted as forest cover. Early spring scenes (Figure 5c) display a sharp contrast between heavily forested areas and pastures having light forest cover. Winter wheat and understory vegetation show bright red, while leafless forest areas are darker. Distinguishing forest cover from barren ground is difficult; consequently, small areas of forest surrounded by fields may not be detected. May and June scenes (Figures 5d and 5e) do not display a sharp contrast between forest and nonforest areas, as light leaf cover blends with understory reflectance. In midsummer (Figures 5f through 5h), forest canopy is in full leaf, and even small areas of forest are identifiable. Fields can be distinguished from forest cover, but accurately defining boundaries is difficult, especially where forest borders pasture or sparsely forested areas. The representation for October (Figure 5i) is similar to that for June, as some fields have been harvested. Remaining agricultural vegetation competes with forest cover, and boundaries are not sharp. Small areas of forest are again difficult to identify. November imagery (Figure 5j) is similar to that for April.

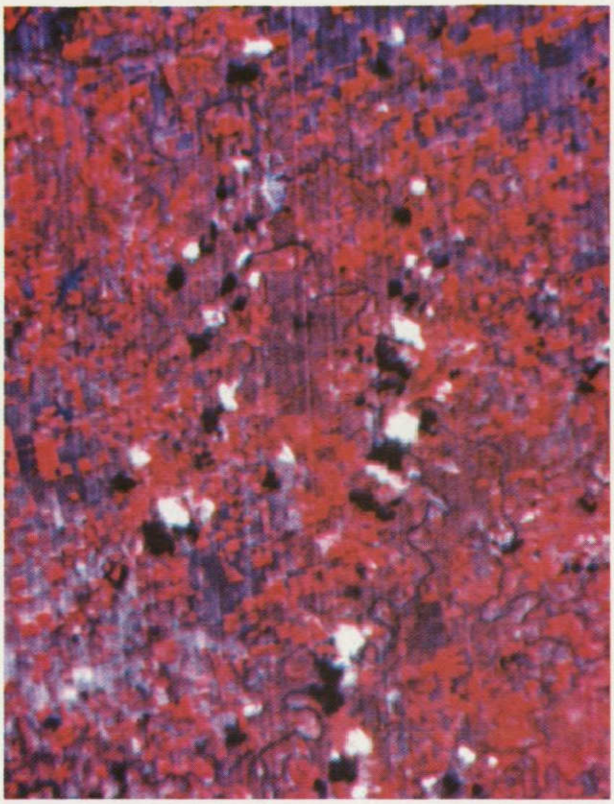


a. February

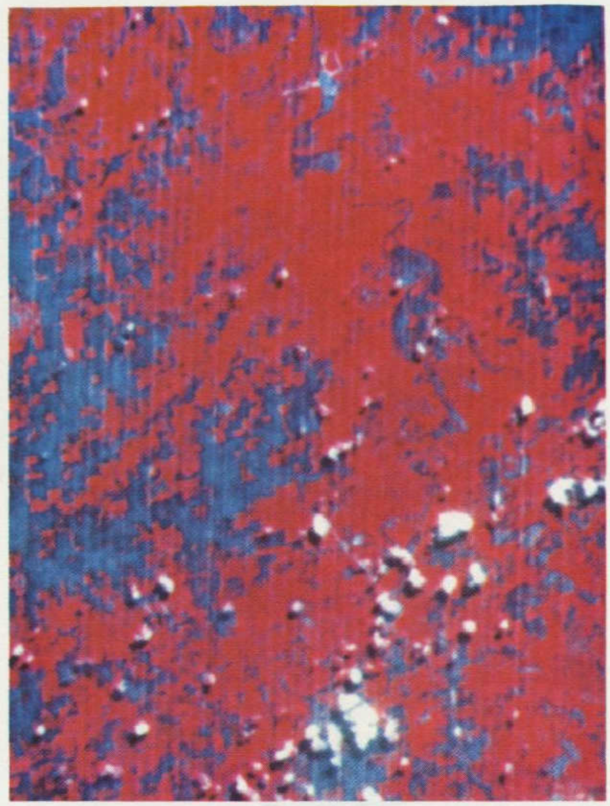


b. March

Figure 5. Seasonal Landsat Images

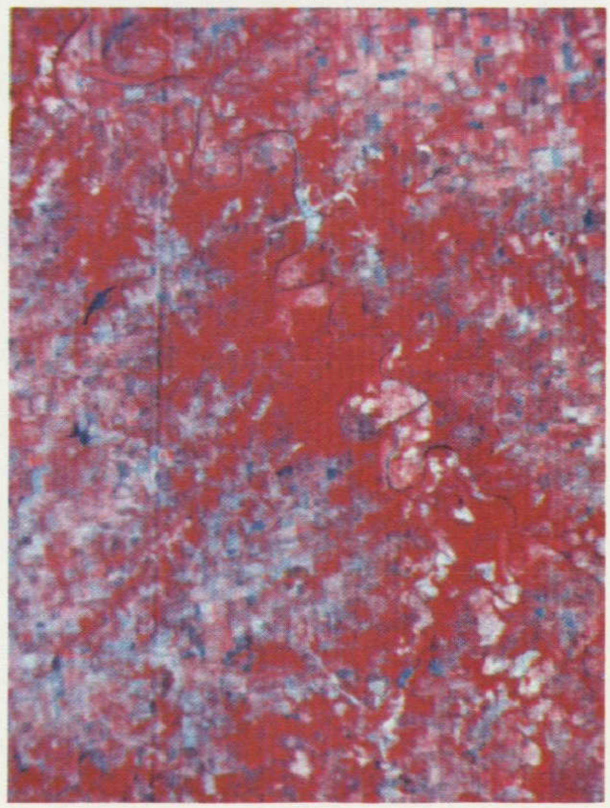


c. April



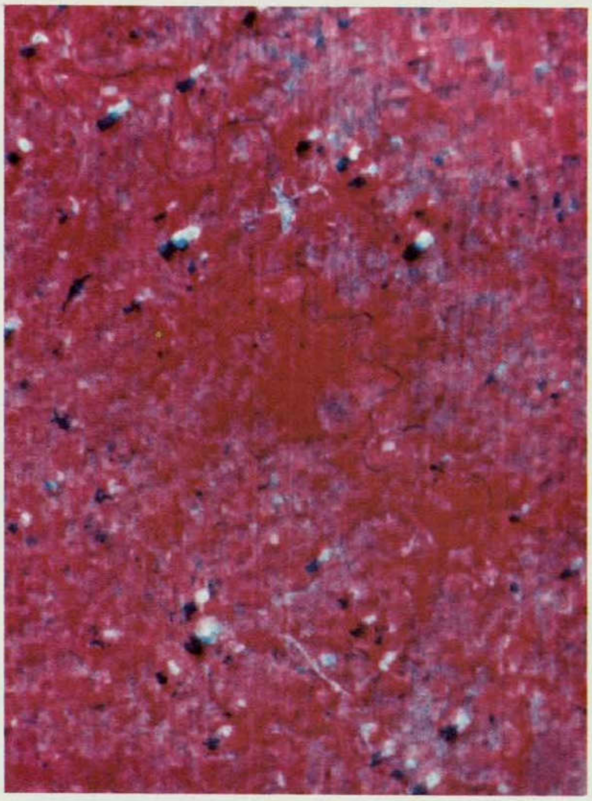
d. May

e. June



f. July

Figure 5. Cont'd



g. August

h. September

i. October

j. November

Figure 5. Cont'd

July is the best single month for interpreting forest cover. Canopy is heavy, winter wheat and oats have been harvested, and corn and soybeans are just beginning to reach significant growth. (Figure 6 shows approximate growing periods for crops and vegetation.) However, there is a tendency to overestimate forest cover due to blending of boundaries and sparsely forested areas.

Two-band color composites using Band 5 exposed through a cyan filter and Band 7 exposed through a red filter were found satisfactory for interpreting forest cover. Addition of Band 4 has both advantages and disadvantages. Agricultural features can be observed with some clarity, but for early spring scenes, the additional band reduces contrast between forest cover and understory vegetation. For summer scenes, contrast is slightly improved. Figure 7 shows two different representations of the scene shown in Figure 5f. Figure 7a represents a three-band composite with Band 4 exposed through a blue filter, Band 5 through a green filter, and Band 7 through a red filter. Composites made from two bands, such as Figure 7b, were easier to register than

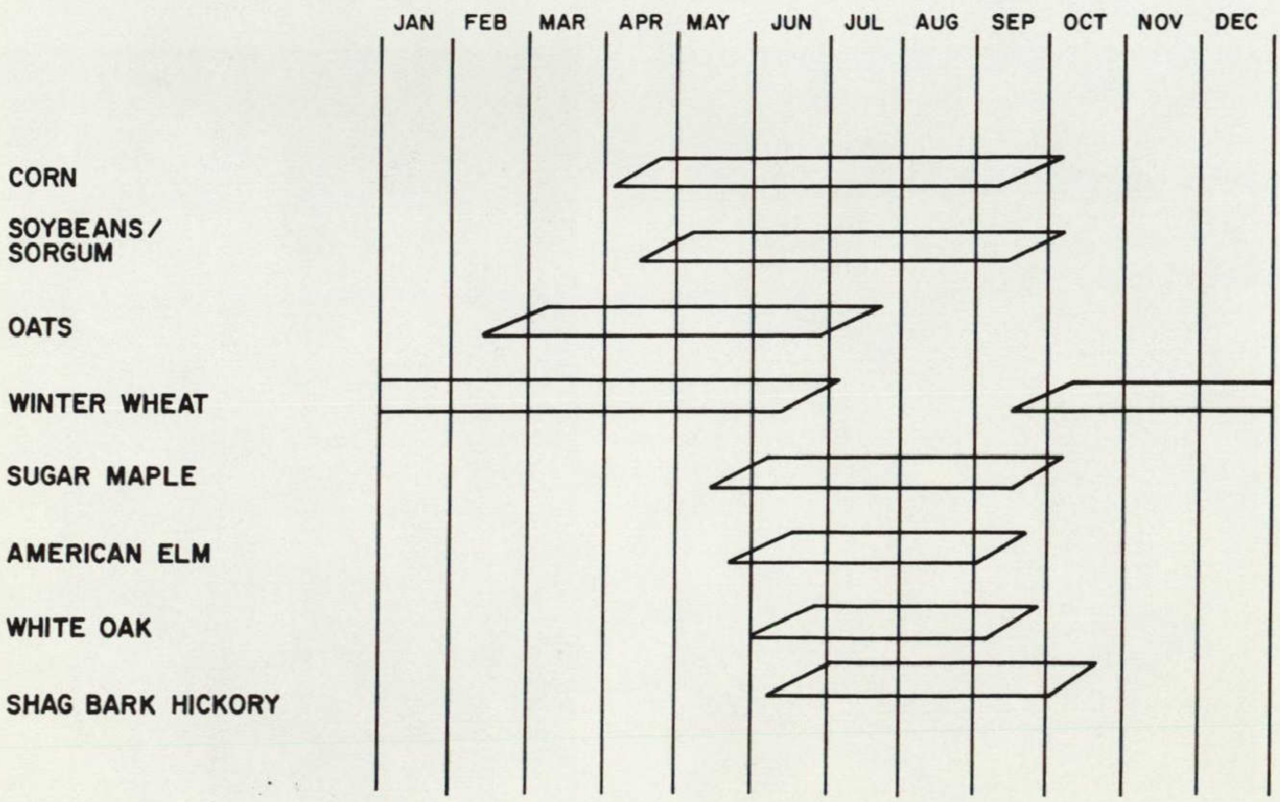
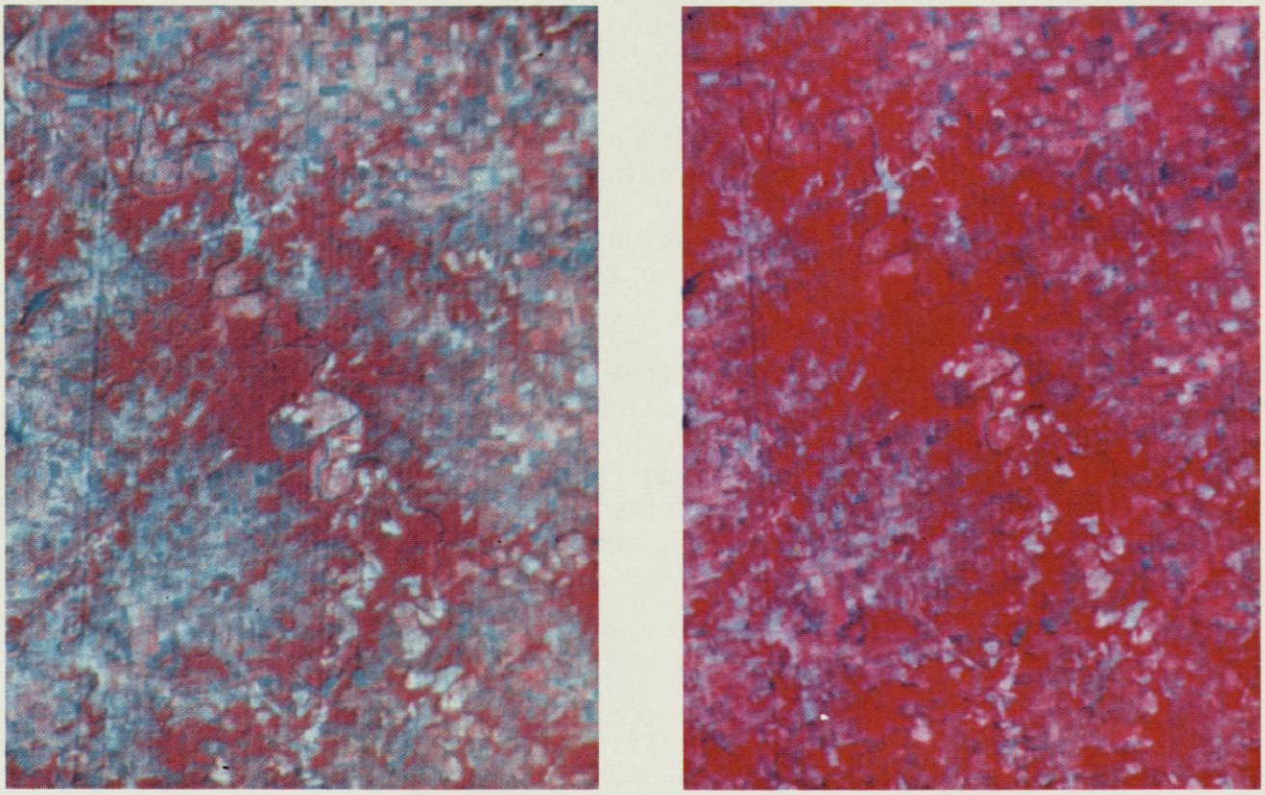


Figure 6. Approximate Growing Seasons of Crops and Trees



a. Three bands

b. Even exposure

Figure 7. Alternative Processing Methods

those made from three bands, and forest areas were adequately represented. Note that there is less contrast between red features in Figure 7b than there is in Figure 5f. Summer scenes such as Figures 5f through 5h were exposed for Band 7 at an exposure time one-half stop less than for Band 5 because of the heavy vegetation cover. This lessened the amount of red in the composite.

Two methods were used for interpretation. Initially, the slides were projected to the desired scale, and tonal values were coded onto a gridded sheet of paper. It later became apparent that 8 x 10 prints could be made from the slides at a convenient scale and that the resulting photographic representation of the project area offered several advantages. The results of these two interpretation methods are discussed in the next two sections.

GRID-CELL MAPPING

Technique

Figure 8 shows the projection box used in grid-cell mapping. The interpreter places a gridded coding form over the glass and projects the slide directly onto the paper at the desired scale. After the color tones are distinguished and assigned a code, the interpreter simply observes each cell on the coding form and enters the code representing the color tone.

This interpretation system has many advantages. It is quick, simple, easy to digitize, and allows for adjustment of scales. Unfortunately, gridded tonal interpretations using Landsat imagery are not sufficiently accurate to provide baseline data upon which environmental monitoring can be based. Interpreted information must be accurate, both in identification and location, and must be reproducible by different interpreters. The results of tests of repeatability and accuracy are discussed below.

Results

The results of repeatability tests indicate a standard error of ±80 cells (out of a possible 2500 cells) among five individuals interpreting forest cover for the same scene.

Interpretations of forest cover by the same individual observing a scene at two different times differed by 53 cells. One cell represents about 0.6 km^2 (160 acres) at the scale used (1:130,000).

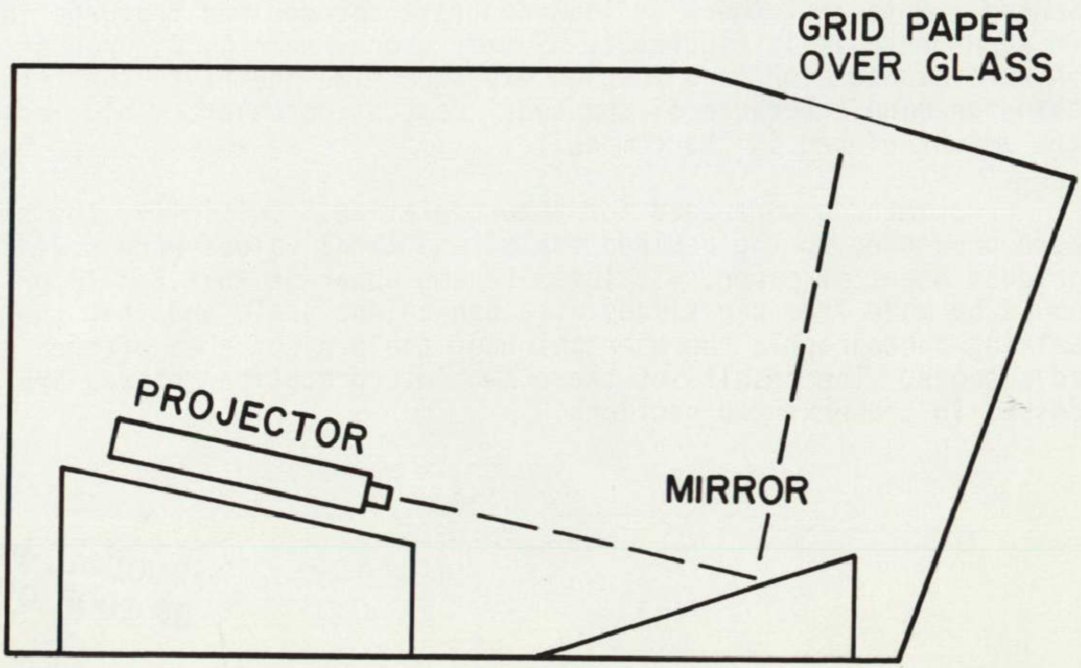


Figure 8. Projection Box

Accuracy tests using six different scenes indicated the following:

1. For summer and fall months, forest cover is represented by a single tone. For spring months, forest cover is best represented by two tones.

2. When using the tone representations described in 1 above, the area of interpreted forest cover corresponds to the area of ground truth forest cover within 86 to 98 percent, depending on the date of the imagery.

3. Comparison on a cell-by-cell basis indicated that interpreted forest cover is correctly identified 62 to 88 percent of the time and that areas are incorrectly classified as forest cover 23 to 32 percent of the time (Table 1).

Table 1. Accuracy of Forest Cover Interpretation

Scene	Percent Forest Cover Correctly Identified	Percent Incorrectly Identified as Forest Cover
August 1973	79	28
November 1973	69	31
May 1974	84	31
March 1975	62	31
May 1975	88	32
July 1976	78	23

Analysis

Figure 9 shows a line printer map of tonal classifications for July 1976. Areas representing missed forest cover and areas incorrectly classified as forest cover are outlined. Some of the errors can be attributed to problems with the ground truth. The forest cover map displays riverside forest cover, such that the entire river is shown as forest cover. The river, however, is quite distinct on the imagery, and cells containing portions of the river are usually classified as non-forest. In two locations, significant areas were misclassified as forest cover on the map used for ground truth. Elimination of these areas increases the area correctly classified to 84 percent and reduces the area mistaken to 17 percent. Unacceptable error still remains, however.

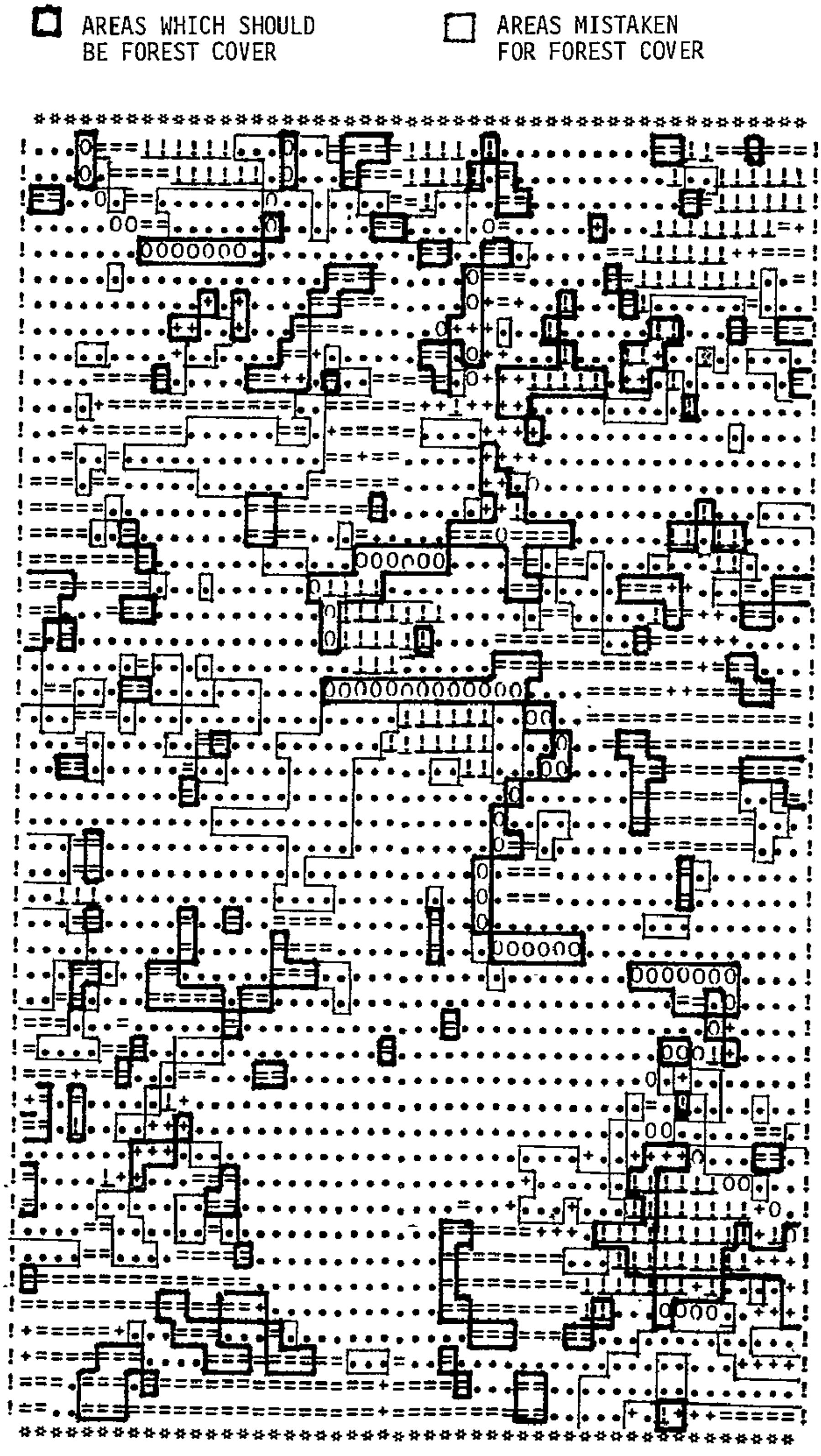


Figure 9. Incorrect Classifications

A second major source of error is delineation of boundaries between forest and nonforest. This is attributed to large cell size. At scale 1:250,000, one cell represents about 647 500 m^2 (160 acres). This reduces to about 162 000 m^2 (40 acres) at scale 1:130,000 and 40 500 m^2 (10 acres) at scale 1:62,500, which is about the limit for enlargement. Perfect registration of intepreted information with ground truth may reduce the comparison error, but it still remains difficult to accurately delineate boundaries with a 40 500 m^2 (10-acre) cell size.

Problems during the interpretation process also contributed to errors. Observers were asked to interpret up to nine different tones or tone combinations. In reality, forest cover, which could be represented by one or two tones, was the only feature of interest. Observers should therefore have been instructed to classify two items--"forest cover" and "other."

Additional work with the grid-cell technique might have resolved these problems, but the technique was abandoned in favor of the dual image mapping technique, which quickly proved promising. This technique is discussed in the next section.

DUAL IMAGE MAPPING

Technique

Dual image mapping, as used here, is the manual interpretation of individual or superimposed images to delineate features of interest. The Zoom Transfer Scope (ZTS) enables the interpreter to examine two images simultaneously in register. This technique was found to be an excellent method of identifying forest cover on enhanced and enlarged Landsat images. Ground truth could be superimposed to evaluate interpreted features. In addition, images taken at different times could be superimposed to facilitate change detection.

Results

Evaluation of seasonal images revealed that no single image provided a perfect representation of forest cover. However, superimposing a snow-covered winter scene on a spring scene and a midsummer scene allowed accurate identification of forest cover.

A spring scene, such as one taken during April, displays forest cover as dark red tones which contrast well with bright red understory vegetation and winter wheat (Figure 10a). Distinguishing between barren ground and forest cover is difficult in some areas, especially where small areas of forest cover are surrounded by agricultural fields (Areas A, I, J, and D).

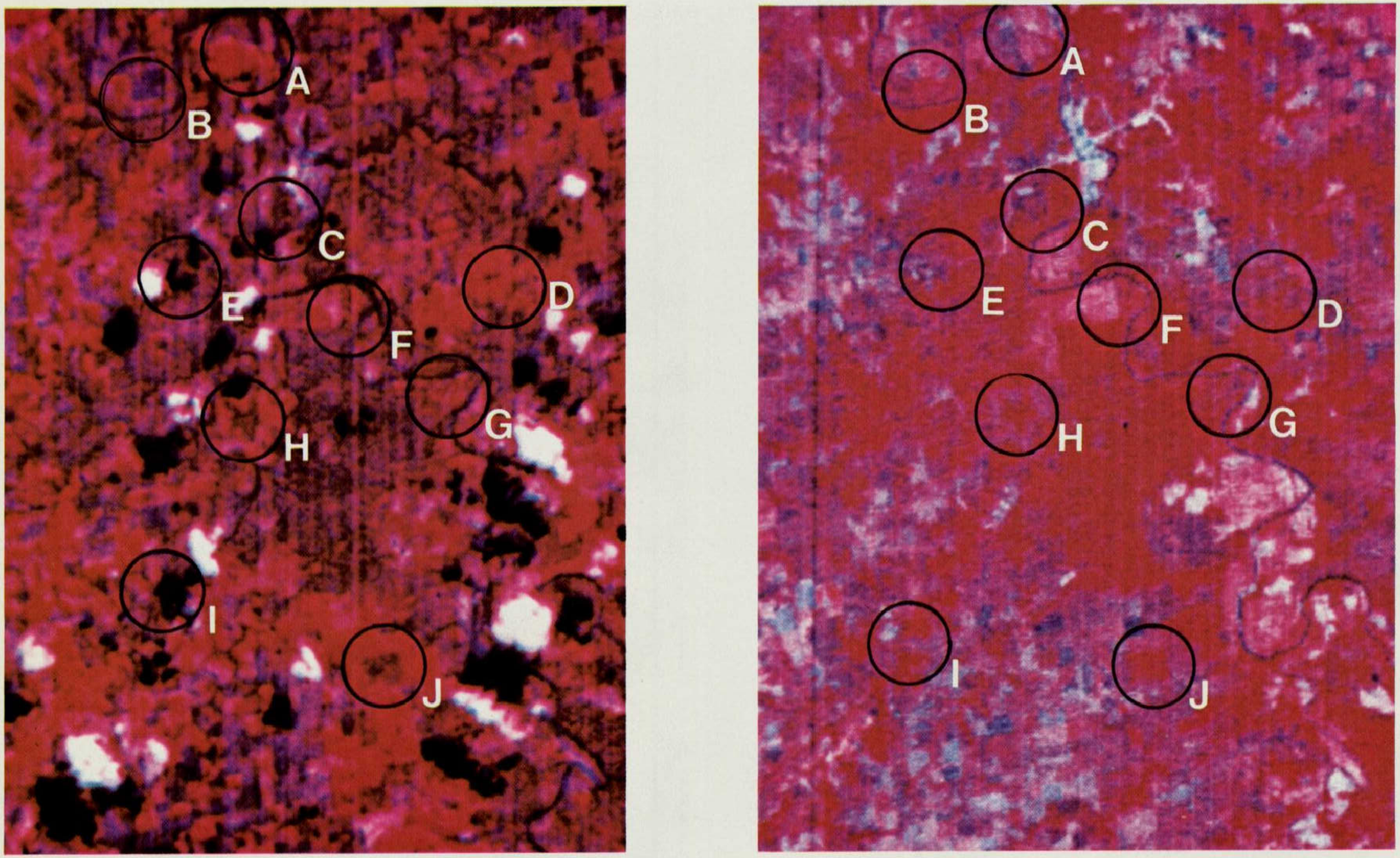
In July, forest canopy is heavy, winter wheat and oats have been harvested, and corn and soybeans are just beginning to reach significant growth (Figure 10b). Forest cover, including small areas, is identifiable. Fields can be distinguished from forest cover, but defining boundaries is sometimes difficult, especially where forest borders pasture or sparsely forested areas (Areas C and E).

The light snow cover shown in the high-contrast panchromatic rendition of Band 7 (Figure 10c) helps to highlight forested areas, and even small areas are defined (Areas A, D, and I). Drainage ways and steep slopes are the principal locations for forest cover within the project area, and these areas contrast with snow-covered fields. Boundary definition presents problems, especially where the transition is from forest to sparse forest to pasture (Areas B and C).

Analysis

Dual image observation using the ZTS is an excellent technique to delineate forested areas. The method most favored is to superimpose winter and summer scenes and refer to the spring scene to establish boundaries between forests and pastures. Evaluation of a few areas shows how the technique works. In Areas D, E, and I of Figure 10, snow cover reveals the actual limits of forest cover from what they appear to be in the summer imagery. In Areas A and B, the spring scene shows dark areas which could be mistaken for forest cover. Both the winter scene and summer scene indicate no forest cover. In Area F, the summer scene shows forest cover, and the boundaries are difficult to distinguish on the winter scene. The spring representation shows boundaries more clearly.

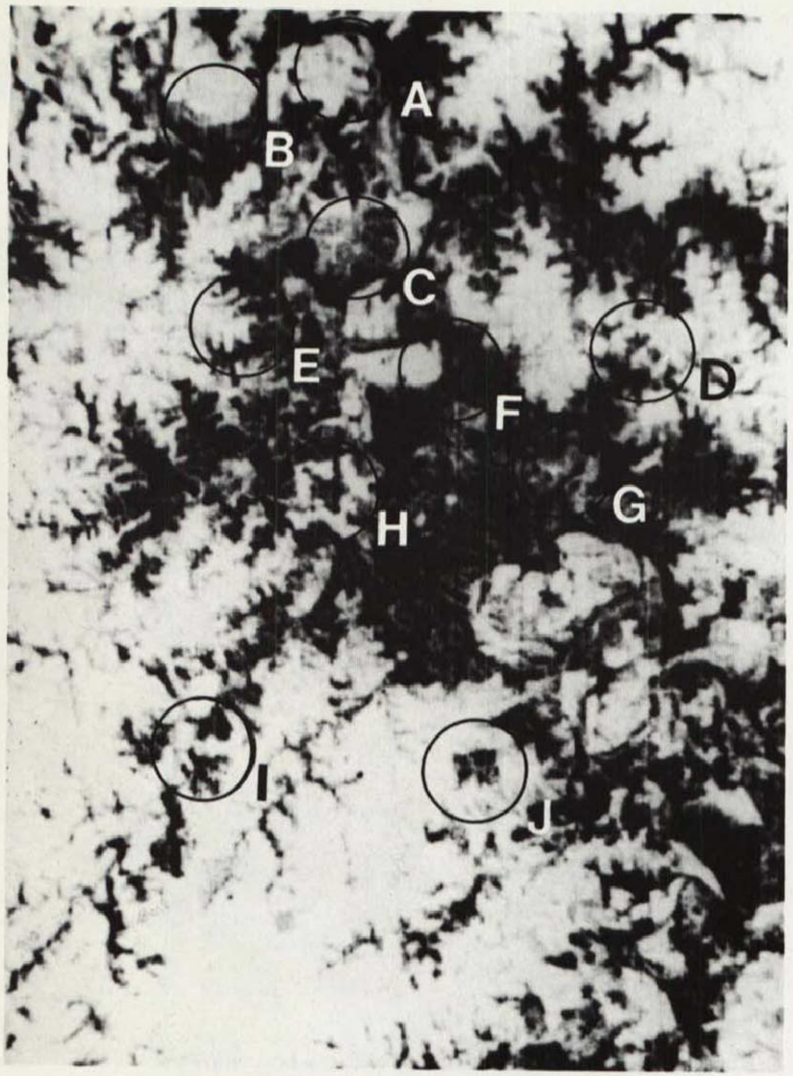
Dual image observation using the ZTS was also found to be an excellent technique for detecting land use changes. Figure 11 shows the August 1973 scene, which represents preproject conditions (enlargement of Figure 5g). Areas of change are delineated on the latest imagery available, October 1976 (Figure 12). Easily distinguishable features include roads, a diversion channel, a recreation area, and tree clearing.



a. Spring

b. Summer

Figure 10. Seasonal Images



c. Winter snow

d. Ground truth

Figure 10. Cont'd

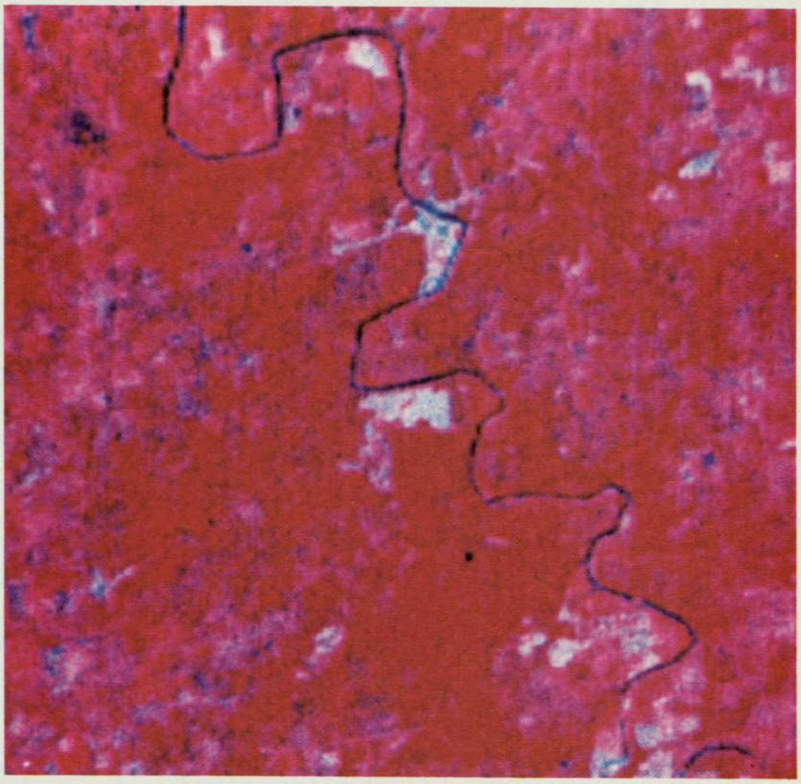


Figure 11. August 1973 Image

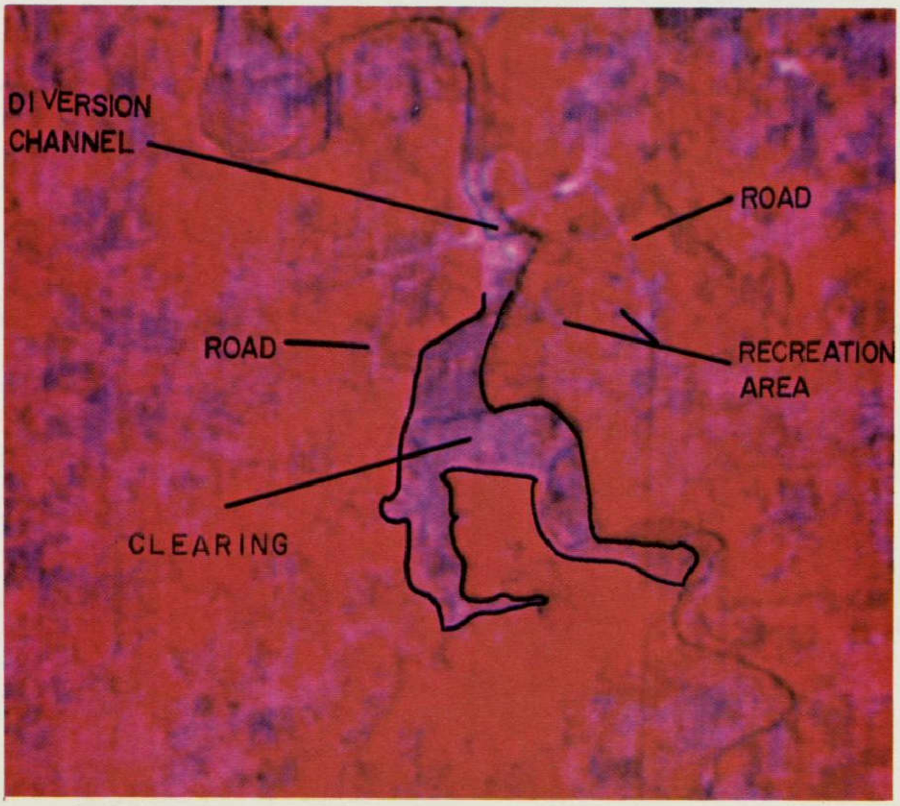


Figure 12. October 1976 Image

3 INTERPRETATION OF AIRCRAFT IMAGERY

APPROACH

High-altitude aircraft imagery (229 mm [9 in.] color infrared) was obtained during this study for use in analyzing the project area and then comparing its usefulness with Landsat imagery. The color infrared (CIR) photographs produce much finer resolution and detail than can be obtained from Landsat imagery. Figure 13 is an October 1976 scene of the study area showing vegetation as red, dam site construction and roads as white, and cleared areas as light blue. Compared to Figure 12 (the enhanced Landsat image), Figure 13 shows the outstanding clarity of detail available in aircraft imagery that simply cannot be obtained from Landsat coverage.

Detailed changes in land use can be more clearly identified on aircraft imagery. In the circled area in Figure 13, construction of recreation trailer pads can be distinguished. However, on the Landsat image (Figure 12), evidence of construction in this area can be identified, but the type of construction cannot be identified. Simple detection of major construction, such as the dam site, clearing, and recreational construction is the level of detail obtainable with Landsat imagery.

Interpretation of aircraft imagery at different levels of detail can yield a variety of information. In this study, two levels of analysis were pursued: a regional scale analysis and a more detailed study area analysis. Both analyses are described and illustrated to show how the aircraft imagery can be used for environmental monitoring and establishment of baseline information.

REGIONAL ANALYSIS

Using the high-altitude imagery, a generalized land use map was prepared to characterize the area around the project area. It was determined that there were three major categories of land use: forest, untilled agricultural (pasture), and tilled agricultural (row crop). These categories could have been broken down into a more detailed system such as that recommended by the U.S. Geological Survey,[4] but a characterization of major land use relationships was all that was required.

The general land use map (Figure 14) was produced using the following method.

---

[4]James R. Anderson et al. A Land Use and Land Cover Classification System for Use With Remote Sensor Data. Professional Paper 964. U.S. Geological Survey, 1976

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 13. October 1976 High-Altitude Aircraft CIR Imagery

Figure 14. Generalized Land Use Map of the Region

Each 229 mm by 229 mm (9 in. by 9 in.) infrared transparency making up the study area (total of five transparencies) was placed on a light table with a sheet of clear acetate placed over it. A separate acetate sheet was used to depict each of the three major land uses. By darkening in the appropriate class with ink, each land use could be separately extracted and mapped. The classified acetate sheets were then individually placed on a light table and overlaid with a paper base map of the study area, and each land use category was colored in with felt tip markers. The diagram in Figure 15 illustrates the process.

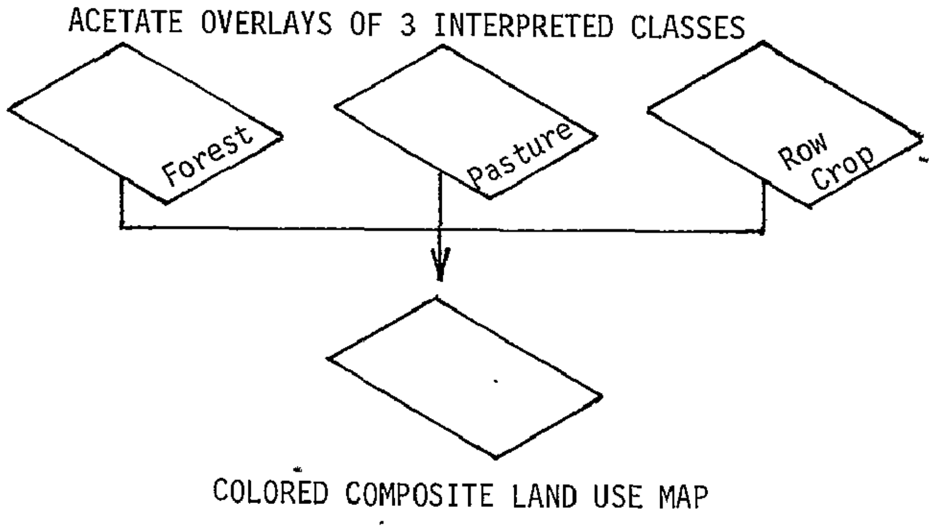


Figure 15. Process for Producing Land Use Map

The resulting map (Figure 14) shows a composite land use pattern typified by forest on sloping ridges and drainage ways, tilled agricultural (crop land) on the uplands, and untilled agricultural land (pasture) in the transition between forest and tilled agricultural. The most important distinction from a monitoring point of view is the ability to identify the boundaries between pasture and forest cover. Pasture/forest boundary areas are preferred habitat for many wildlife species and should be monitored to determine the degree of impact from reservoir construction. These transition areas can be identified by using the classification map and the original imagery to depict boundaries of the areas.

Natural vegetative succession--where it occurs and how fast it proceeds--is another important monitoring topic. Such areas cannot be effectively identified using Landsat imagery, but can be monitored using high-altitude aircraft imagery.

The regional scale map was easily produced without extensive time, effort, or training in interpretation technique. The regional approach was pursued to quickly and easily determine the general land use classes within the area that characterize the region. This method of analysis can be easily replicated and should be more widely used in the future. The only significant limitation appears to be the initial acquisition of the aircraft imagery which must be requested through NASA on a per mission basis.

DETAILED STUDY AREA ANALYSIS

Another level of analysis using aircraft imagery was performed to determine the forest types which might be affected by reservoir construction. By using a process of overlaying two environmental factors (slope and aspect) with the actual forest cover interpreted from high-altitude aircraft photos, a predicted forest type was produced. Figure 16 illustrates the overlay process.

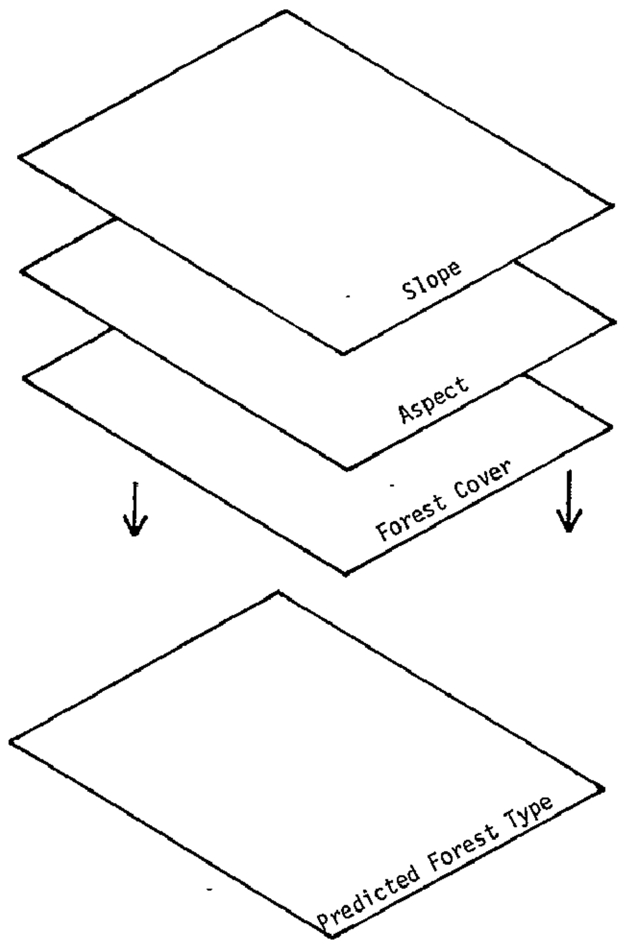


Figure 16. Overlay Concept for Deriving Forest Type

Slope

Slope categories were taken from the project's Environmental Impact Assessment. Four slope categories were used:

1. 0 to 3 percent, floodplain
2. 3 to 10 percent, valley side
3. 10 percent and above, valley side
4. 0 to 3 percent, upland.

Major vegetation stands tend to group themselves within these slope categories or drainage classes. Table 2 shows the forest type classes and how they respond to slope categories. For example, oak-hickory forest tends to occur mainly on slopes of 3 to 10 percent.

Table 2. Criteria for Forest Type Classes[5]

Forest Type	Criteria						
	Slope				Aspect		
	0-3% Flood Plain	3-10%	10% and Above	0-3% Upland	South-west	South-east	North-east
Oak		X	X	X	X	X	
Oak-Hickory		X				X	X
Oak-Hickory-Maple			X			X	
Hickory-Maple-Walnut			X				X
Silver Maple-Elm	X				NA	NA	NA

Aspect

Vegetation also responds to the direction that ridges face with respect to the sun. Southwest facing ridges receive maximum sun and tend to have more heat-tolerant species than do northeast facing slopes. For example, oaks, a more heat-tolerant species, prefer south facing slopes while maples, which are more shade-tolerant, prefer east facing slopes.

[5] Environmental Impact Assessment, Clarence Cannon Dam and Reservoir. Final report to the U.S. Army Corps of Engineers, St. Louis District. Missouri Botanical Garden, October 1974

The aspect classes used were (1) southwest facing, (2) southeast facing, and (3) northeast facing. Table 2 also shows aspect classes that major forest types were found in.

Forest Cover

Forest cover was mapped simply by interpreting forested areas from the high-altitude aircraft imagery in the same manner as described for the generalized land use map.

Composite Map

The slope, aspect, and forest cover were each mapped on a transparent film. By overlaying the three films in register on a light table, the desired combination could be seen. The separate forest types were then mapped by placing a clear acetate sheet over the three base sheets. Figure 17 depicts the process by which the individual factors were combined to make the final map.

The composite map shown in Figure 18 is the end product. This map could be used to study and analyze in detail the areas that are subject to inundation or clearing. This information could be valuable in determining:

1. Loss of specific wildlife habitat types

2. Changes in wildlife distribution and recovery rate from habitat loss

3. Imminent threat to an endangered species of plant or animal associated with one of the major forest types

4. Future conditions that might influence certain types of development or construction

5. Amount and type of vegetation which will be permanently inundated by impoundment.

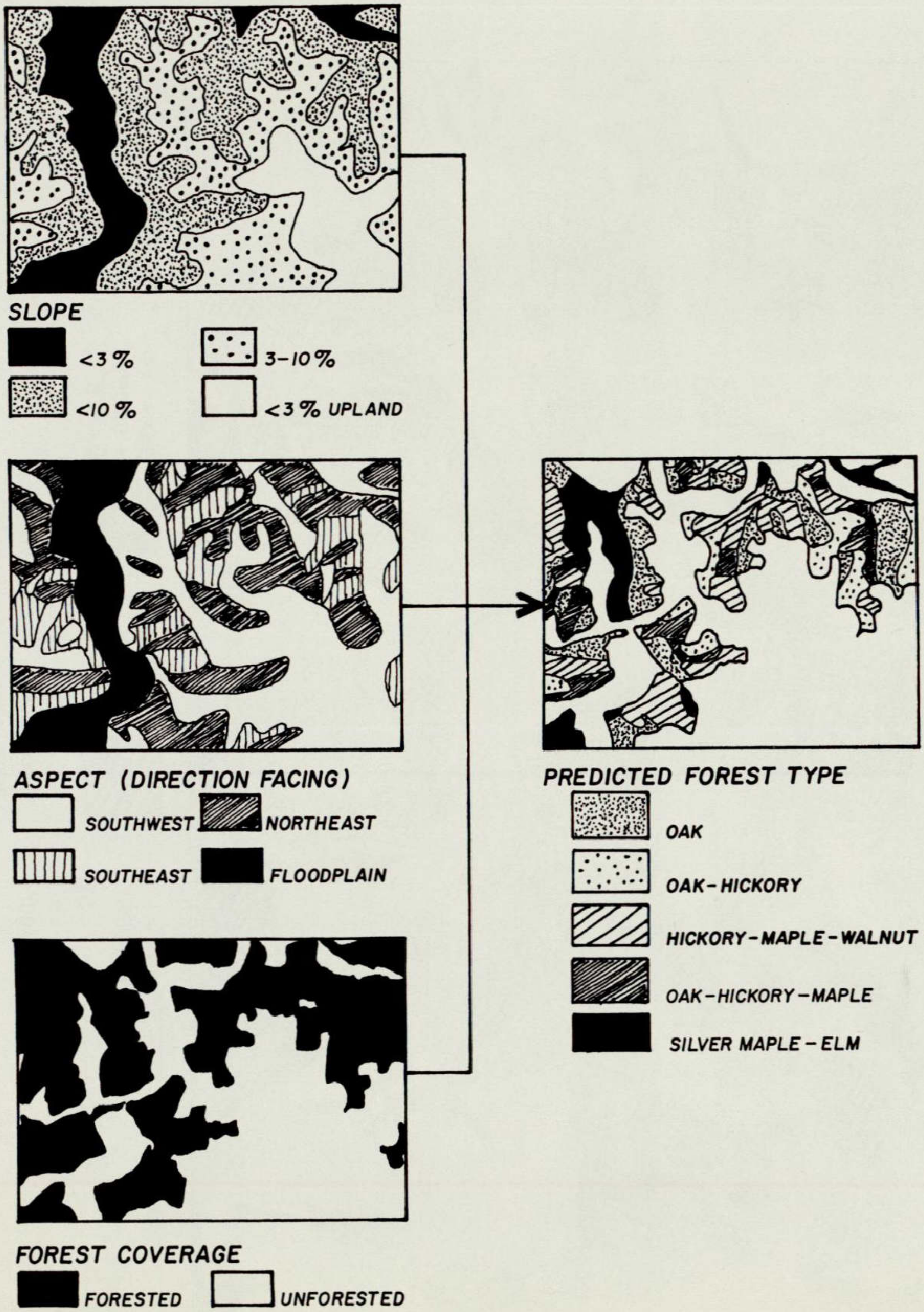


Figure 17. Process for Producing Predicted Forest Type Map

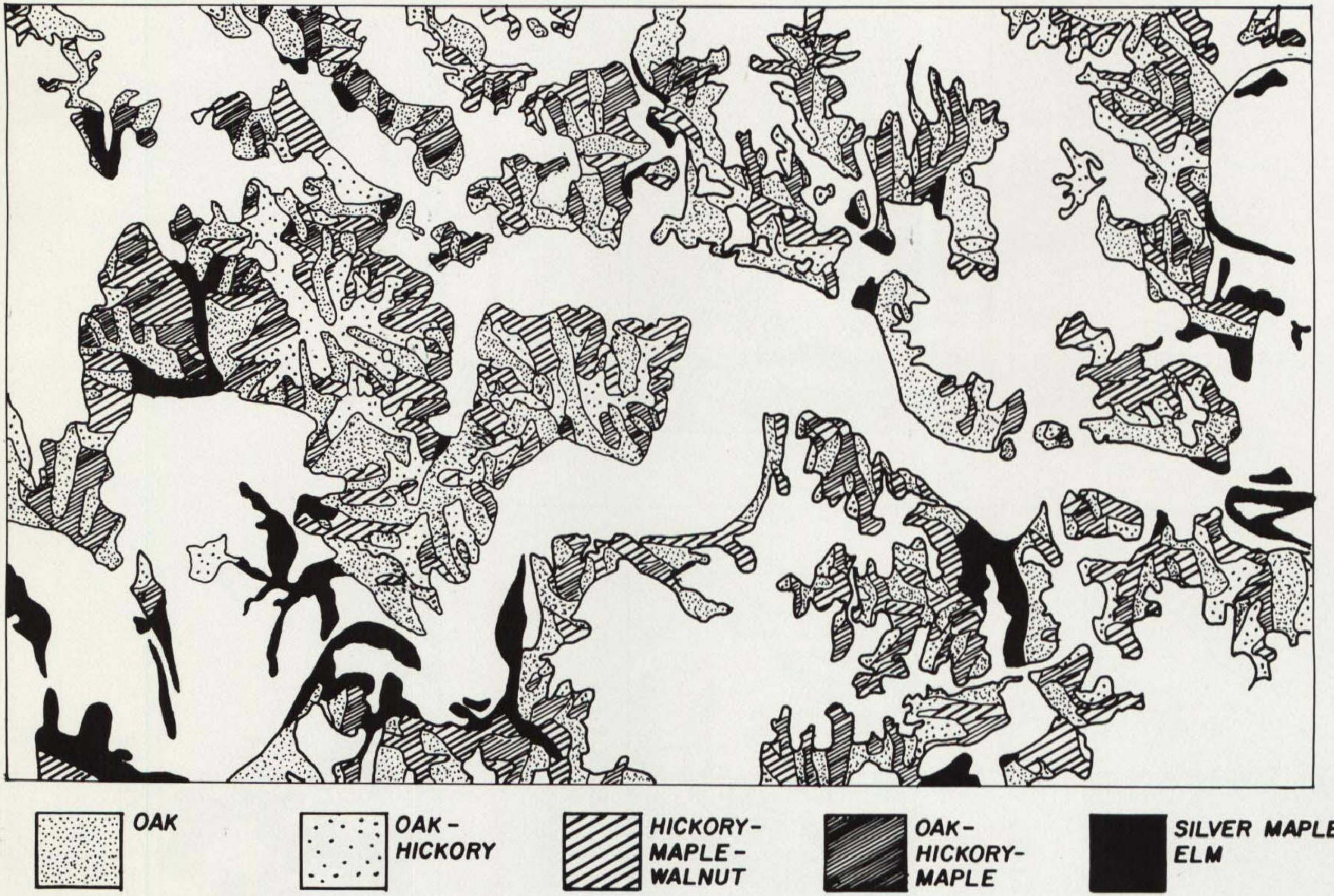


Figure 18. Predicted Forest Type Map
Approximate scale = 1:60,000

4 MACHINE PROCESSING

Comparison of Landsat Computer-Compatible Tape (CCT) output and photographic enhancements reduces to a tradeoff between quantity of information and simplicity. Data posting of individual multispectral scanner bands provides numerical values from 0 to 64 representing the brightness values of the data elements. Each data element represents an area of about 4050 m^2 (1 acre). At a scale of 1:62,500 (about the limit for enlargement), one line printer character (one cell of tonal interpretation) represents 40 500 m^2 (10 acres).

Landsat CCT is more difficult and expensive to use than photographic Landsat products. One set of CCT costs 20 times what one set of Landsat transparencies costs. In addition, computer processing is 5 to 10 times more expensive than optical processing. Optical processing offers more flexibility to modify the format, scale, and tonal representation of ground features.

Interpretation of Landsat CCT line printer output is similar to interpretation of coded cells of tonal values. It is less difficult to delineate boundaries between forest and nonforest with a 4050 m^2 (1 acre) cell size than with a 40 500 m^2 (10 acre) cell size, but direct comparison with ground truth is difficult, due to distortions in the printout geometry of the Landsat CCT line printer output.

The advantage of increased accuracy using Landsat CCT is most apparent during initial delineation of forest areas. However, since high-altitude aircraft imagery is superior to Landsat imagery for delineation of forest areas, this advantage is not of great importance. Optical processing is therefore more practical than computer processing of Landsat CCT for the type of environmental monitoring done in this study.

5 CONCLUSIONS

Landsat imagery can be used effectively as a baseline for detection of environmental change resulting from construction of a major inland reservoir. Forest cover can be observed adequately on two-band composite enlargements at a scale of 1:130,000. Forest cover delineated on Landsat enlargements compares accurately with ground truth at a scale of 1:250,000. A dual image mapping technique superimposing winter, summer, and spring scenes using the Zoom Transfer Scope facilitates the determination. The same technique can be used to detect changes in the project area resulting from construction activities. High-altitude aircraft imagery can also be used to interpret changes in land use and forest type. Construction operations can be more clearly detailed on the air photos than on Landsat imagery.

A program to monitor the anticipated physical and biological impacts identified in preproject environmental studies (Table 3) would require annual spring and summer Landsat coverage supplemented with high-altitude aircraft imagery 5 years after impoundment and, for selected areas, low-altitude imagery 3 to 5 years after impoundment. Continued study will determine how Landsat and high-altitude aircraft imagery can be used to detect additional changes in the project as they occur. Following this, efforts will be directed toward model building and evaluation to determine if environmental impacts in other areas having similar preproject environments can be predicted.

Table 3. Anticipated Environmental Impacts

Physical Impacts

Deltas will be created where tributaries enter the reservoir. More and more upstream areas will be flooded.

Downstream scour could lead to down-cutting of tributaries, which could continue into agricultural land.

Ground water depth and water quality (from septic tanks) will change.

Increased soil moisture near the reservoir will result in shift towards more hydrophytic plant communities.

Biological Impacts

Dramatic shifts in species abundance in areas adjacent to the impoundment will occur.

Patterns of animal populations will change in response to changed patterns of forest vegetation and species composition.

Downstream terrestrial species will be impacted by change in farming practices.

Changes in aquatic plant and animal species will occur in response to impoundment.

Turbidity will be reduced considerably after turbulence is reduced and particulate matter has settled out of suspension.

Eutrophication could occur if nutrient levels and availability are not limited and turbidity is reduced.

APPENDIX A

Imagery Available for Study

Excellent multi-level coverage is available for study of the Clarence Cannon Reservoir area. Two dates of low-altitude aircraft coverage are available in black and white, 229-mm (9-in.) format. Approximate photo scale is 1 mm = 12 m (1 in. = 1000 ft). The photographs were prepared for the St. Louis District, U.S. Army Corps of Engineers, by Surdex Corporation, Chesterfield, MO. The dates of coverage are 15 December 1962 and 1 April 1974.

Four dates of NASA high-altitude aircraft imagery are available. Sensor characteristics are shown in Table A1. Dates of coverage are 26 February 1975, 17 April 1975, 24 May 1976, and 15 October 1976.

Table A1. Sensor Characteristics

Sensor Type:	Vinten	Vinten	RC-10
Lens Focal Length:	44.45 mm (1 3/4 in.)	44.45 mm (1 3/4 in.)	152.4 mm (6 in.)
Film Type:	Plus X 2402	Infrared Aerographic, 2424	Aerchrome Infrared, 2443
Filtration:	SCHOTT GG475 + SCHOTT BG18	SCHOTT RG645 + CORNING 9830	WRATTEN 12 + .10C + 2.2AV
Spectral Band:	475-575 nm	690-760 nm	510-900 nm

Landsat imagery was obtained on a periodic basis over a 4-year period. Table A2 shows the day, month, and year of usable coverage obtained for this study.

Table A2. Landsat Coverage

	1973	1974	1975	1976
January				14
February		1	6	1,19
March			4,14,22,31	
April		15		
May		20	15	
June			2	30
July		19	17	11,12
August	5	19	5,22,23	
September		5	27	
October	16,17			9
November	22			
December		5		

APPENDIX B

Optical Processing Hints

The following discussion will facilitate the production of Landsat enlargements. The production and projection of slides begins with selection of the copied slide scale for projection at the required scale for interpretation. Table B1 shows that the optical processing system can be used for projected scales of 1:130,000 and 1:62,500 if slides can be copied at the scales shown. System limits are exceeded only because of limitations of the PB-5 bellows attachment and the projection box.

The projection box used in this study could project at distances from 0.7 to 1.0 m (30 to 40 in.). The projector had a 76-mm (3-in.) focal length lens and a zoom lens with 102- to 152-mm (4- to 6-in.) focal length. The projection system (Table B2) could accommodate magnifications from 5X to 12X, 14X, and 16X for various distance/lens combinations.

If, for example, a projected scale of 1:62,500 is required, a copied slide scale of 1:1,000,000 or 1:500,000 can be used. Table B3 shows that, assuming an original scale of 1:1,000,000, a magnification factor of 1X or 2X is needed to obtain the required slide scale. Table B4 shows that a convenient bellows setting for magnification at 2X is bellows interval 118.0 and subject distance 2.3 cm with lens in the normal position. The PB-5 instruction manual should be consulted for detailed instructions on use of the PB-5 bellows attachment.

An optical processing system can operate at values different from those shown in the tables, but these values were found to be convenient. The zoom lens on the projector gives a great deal of flexibility so that enlargements need not be made with high precision.

Table B5 shows approximate magnifications for obtaining prints from 24 mm by 35 mm slides. Unless otherwise specified by the customer, commercial processors will usually crop the sides to fit the 24 mm slide dimension to the corresponding 76-, 127-, or 203-mm (3-, 5-, or 8-in.) standard format. This explains the discrepancies in the table where the long dimension of an 8X enlargement is greater than that of an 8.5X enlargement. A final print size can usually be specified. For example, to obtain a print at scale 1:250,000 from a slide of scale 1:1,000,000, the customer should ask for a 96 mm by 140 mm (3.8-in. by 5.5-in.) print format.

Table B1. Magnification Factors for Projecting to Various Scales

		Projected Scale		
		250,000	130,000	62,500
Copied Slide Scale	1,000,000	Exceeds	7.7	16
	500,000	Exceeds lower limit		8
	250,000	Exceeds	lower	limit
	130,000	Exceeds	lower	limit

Table B2. Magnification Factors for Various Combinations of Projector Lens f and Projected Distance

			f of Projector Lens		
			76 mm (3 in.)	102 mm (4 in.) Zoom	152 mm (6 in.)
Projected Distance	0.7 m	(30 in.)	10	7.5	5
	0.9 m	(36 in.)	12	9	6
	1.1 m	(42 in.)	14	10.5	7
	1.2 m	(48 in.)	16	12	8

Table B3. Magnification Factors to Obtain Copied Scales

Original Scale	Copied Scale 1:1,000,000	1:500,000	1:250,000	1:130,000	1:62,500
1:1,000,000	1	2	4	Exceeds	
*1:500,000	__	1	2	3.8	Exceeds
*1:130,000	--	--	--	1	2.1

*Scales may be slightly different but deviations can be accommodated by zoom lens of projector used during later step.

Table B4. Convenient Settings for Copying With the PB-5 Bellows Attachment

Magnification Factor	Subject Distance, cm	Bellows Interval	Lens Position
0.8	5.7	50.0	Normal
1	5.1	62.5	Normal
2	2.3	118.0	Normal
2	6.4	66.0	Reverse
4	5.0	178.0	Reverse

Table B5. Approximate Magnifications for Obtaining Prints From Slides

Magnification	Print Size, mm (in.)
2.0	48 (1.9) x 70 (2.8)
3.2	76.2 (3) x 127.0 (5)
4.0	96 (3.8) x 140 (5.5)
5.3	127.0 (5) x 177.8 (7)
8.0	192 (7.6) x 280 (11)